

WHAT WE CLAIM ARE:

1. A method of manufacturing a solid state imaging device, comprising:
  - (a) forming photosensors, disposed on a semiconductor substrate in a matrix shape, for photoelectrically converting incident light into signal charges, and forming a light shielding film above said photosensors, said light shielding film having openings and increasing a height from a surface of the semiconductor substrate near the openings;
  - (b) forming a first insulating layer on the semiconductor substrate, said first insulating layer covering said light shielding film and being made of additive-containing silicon oxide;
  - (c) reflowing said first insulating layer to form downward convex curved surfaces;
  - (d) forming upward and downward convex inner lenses on said reflowed first insulating layer above the openings, said inner lens being made of silicon nitride;
  - (e) forming a second insulating layer covering said inner lenses, said second insulating layer having a planarized surface and being made of silicon oxide based insulator;
  - (f) forming color filters on the planarized surface of said second insulating layer;
  - (g) forming a planarizing layer of transparent material covering said color filters;
  - (h) forming micro lenses on said planarizing layer; and
  - (i) forming a low refractive index layer covering said micro lenses, said low refractive index layer having a refractive index lower than a refractive

index of said micro lens.

2. The method of manufacturing a solid state imaging device according to claim 1, wherein the additive-containing silicon oxide used in said step (b) is BPSG.

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3. The method of manufacturing a solid state imaging device according to claim 1, wherein said step (a) forms said photosensors by forming a p-type well in an n-type semiconductor substrate and forming a plurality of n-type regions in said p-type well.

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4. The method of manufacturing a solid state imaging device according to claim 3, wherein said step (a) forms a vertical channel adjacent to each column of said photosensors and a plurality of transfer electrodes above said semiconductor substrate, said transfer electrodes alternately covering said vertical channels and  
15 extending in a direction crossing said vertical channels.

5. The method of manufacturing a solid state imaging device according to claim 1, wherein said step (d) comprises:

(d1) depositing a first silicon nitride film on said reflowed first  
20 insulating layer by chemical vapor deposition;  
(d2) planarizing a surface of said first silicon nitride film and forming lower convex lenses;  
(d3) depositing a second silicon nitride film above said  
semiconductor substrate by chemical vapor deposition, said second silicon nitride  
25 film covering said lower convex lenses; and

(d4) forming upper convex lenses by etching said second silicon nitride film by using a mask having a lens pattern.

6. The method of manufacturing a solid state imaging device according to claim  
5 5, wherein said step (d2) etches back said first silicon nitride film.

7. The method of manufacturing a solid state imaging device according to claim  
5, wherein said step (d2) chemical-mechanical-polishing said silicon nitride film.

10 8. The method of manufacturing a solid state imaging device according to claim  
5, wherein said step (d4) comprises steps of:

forming a resist pattern having plan shapes of said upper convex  
lenses to be formed on said second silicon nitride film; and

heating and softening said resist pattern to make said upper convex  
15 lenses have a spherical surface.

9. The method of manufacturing a solid state imaging device according to claim  
5, wherein said silicon oxide based insulator used in said step (e) is BPSG.

20 10. The method of manufacturing a solid state imaging device according to  
claim 5, wherein said step (h) comprises steps of:

forming a resist pattern having plan shapes of said micro lenses to  
be formed on said planarizing layer; and

heating and softening said resist pattern to make said micro lenses  
25 have a spherical surface.

11. The method of manufacturing a solid state imaging device according to claim 10, wherein in said step (h) said micro lenses are formed to have a thickness of 0.5  $\mu\text{m}$  or thinner.

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12. The method of manufacturing a solid state imaging device according to claim 1, further comprising a step of disposing a transparent plate on said low refractive index layer.

10 13. The method of manufacturing a solid state imaging device according to claim 12, further comprising a step of disposing a back insulating plate on an adhesive layer formed on a bottom surface of said semiconductor substrate.

14. The method of manufacturing a solid state imaging device according to  
15 claim 13, further comprising forming leads extending from said semiconductor substrate to said back insulating plate.

15. A method of manufacturing a solid state imaging device, comprising steps of:

20 (a) forming a semiconductor structure having: photosensors disposed in and above a semiconductor substrate in a matrix shape, the photosensors photoelectrically converting incident light into signal charges; vertical CCDs for transferring the signal charges generated in the photosensors in a vertical direction; a horizontal CCD for transferring the signal charges  
25 supplied from the vertical CCDs in a horizontal direction; and a light shielding film

having openings above the photosensors;

(b) forming a first insulating layer on said semiconductor structure,  
said first insulating layer being made of additive-containing silicon oxide;

(c) reflowing said first insulating layer and forming upward and  
5 downward convex inner lenses on said reflowed first insulating layer and above  
the photosensors, said inner lenses being made of silicon nitride;

(d) forming a second insulating layer covering said inner lenses and  
made of silicon oxide based insulator;

(e) planarizing an upper surface of said second insulating layer;

10 (f) forming color filters on the planarized upper surface of said  
second insulating layer;

(g) forming a transparent flat layer covering said color filters, said  
transparent flat layer being made of transparent material;

(h) forming micro lenses on said transparent flat layer;

15 (i) forming a low refractive index layer covering said micro lenses,  
said low refractive index layer having a refractive index lower than a refractive  
index of said micro lenses;

(j) disposing a transparent plate on said low refractive index layer;

and

20 (k) packaging said semiconductor structure disposed with said  
transparent plate.

16. A solid state imaging device comprising:

a semiconductor substrate having: photosensors disposed in a  
25 matrix shape for photoelectrically converting incident light into signal charges;

vertical transfer channels for transferring the signal charges generated in the photosensors in a vertical direction; and a horizontal transfer channel for transferring the signal charges supplied from the vertical transfer channels in a horizontal direction;

5                    first and second electrodes formed above the vertical transfer channels and extending in a direction crossing the vertical transfer channels;

                    a light shielding film formed above said first and second electrodes ;

                    upward and downward convex inner lenses made of silicon nitride,  
10    at the height level above said photosensors and at a process level after forming said light shielding film;

                    micro lenses formed above said inner lenses;

                    a low refractive index layer covering said micro lenses, said low refractive index layer having a refractive index lower than a refractive index of  
15    said micro lenses; and

                    a transparent plate disposed on said low refractive index layer.

17.    The solid state imaging device according to claim 16, wherein a thickness of said micro lens is 0.5  $\mu\text{m}$  or thinner.

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18.    The solid state imaging device according to claim 16, further comprising a plurality of leads connected to said semiconductor substrate.

19.    The solid state imaging device according to claim 18, further comprising an  
25    insulating protection plate adhered to a bottom surface of said semiconductor

substrate.

20. The solid state imaging device according to claim 16, wherein said inner lens includes a downward convex lens area and an upward convex lens area.

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21. The solid state imaging device according to claim 20, wherein said upward convex area has a plan shape broader than said downward convex lens area.

22. The solid state imaging device according to claim 20, wherein said light  
10 shielding film increases a height thereof from a surface of said semiconductor substrate near the openings, and said inner lens is formed inside an area where the height of said light shielding film increases.

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